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PIONEER MARS MISSION STUDY
EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

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Introduction

For several years, NASA's plans for Mars exploration have included a 1979 Viking Mission as a logical follow-on to the 1975 Viking Mission. Future budget estimates are not firm though, and they may allow resources for Mars exploration which will not be sufficient for an ambitious and expensive mission such as Viking.

Rather than abandoning Mars exploration until some time when budgets are more favorable, NASA would like the option to continue by flying more modest missions. One such option would be to base the spacecraft on the Pioneer Venus design which is being developed for launch in 1978. Such a mission could provide a low cost Mars option if the spacecraft changes could be minimized, and if costly new developments to perform Mars science could be minimized.

This report will summarize the results of a study of two Pioneer Mars mission concepts which do provide low cost and scientifically interesting options for continued Mars exploration.

The two Pioneer Mars Missions are:

1. A Surface Penetrator Mission which will perform in-situ surface and subsurface science at many locations and
2. An Aeronomy-Geology Mission which will perform in-situ orbital science and remote sensing of the surface.

SURFACE PENETRATOR MISSION

Introduction and Mission Concept

Many questions about Mars remain to be answered, even after centuries of observation from Earth and the surprising results from Mariner 9. Viking '75, by soft landing experiment packages, will conduct a large number of investigations at each of the two landing sites.

The surface penetrator mission can continue Mars exploration by carrying instruments which can benefit from its unique features: The ability to firmly implant sensors in subsurface material and, the ability to implant sensors at widely scattered locations on the surface. In addition, the low cost of penetrator missions allows them to fit easily into multi-mission strategies for the long range exploration of Mars.

The basis of surface penetrator missions is the ability of the penetrator vehicle to carry science instruments through the atmosphere entry and surface penetration environments, and successfully implant them at or below the surface. Once implanted, the instruments will perform pre-programmed or commanded tasks and transmit their results to the orbiting spacecraft. The science that can be carried within a penetrator is limited only in volume and data quantity.

Science

There are several investigations which can be performed with instruments that are compatible with the penetrator design. For example, the long term natural seismicity of Mars can be monitored by an array of three or more implanted seismometers. The seismometer design used on Viking or a modified commercial geophone design are both good candidate instruments.

The elemental abundance of the subsurface material can be measured at locations chosen to investigate the large scale variations in compositions, including the polar caps. A leading candidate instrument is the α -proton backscatter instrument developed from the instrument flown to the Moon on Surveyor.

Other investigations can be performed by sensors which, although not prime instruments, can provide interesting information. One of these is the determination of local subsurface structure at the implant site by using the accelerometer carried to measure implant depth. Another is the determination of water presence by using a simple aluminum oxide hygrometer.

There are other investigations which appear feasible to perform with penetrators, but, for which some questions must be answered before instruments can be defined. Foremost among these is the measurement of heat flow from the planet. The question to be resolved in this case

is the exact design of an instrument that can measure the temperature gradient very accurately after the implant acceleration.

Another is the measurement of local crustal structures by using an active seismic sensor. The question to be resolved is the exact design of the mechanism used to deploy explosive charges after the penetrator comes to rest.

Measurement of chemical composition by a different technique is another possible experiment. A neutron activation experiment, for example, could be carried if an acceleration and sterilization tolerance can be developed.

Another promising experiment is measurement of the subsurface volatiles inventory at the implant site. A scanning calorimeter can be used to determine CO₂ and H₂O quantities. The problem to be solved is the design of the mechanism used to collect a soil sample and seal it into the oven.

A sample penetrator payload which includes the compatible instruments is shown in Table 1

Table 1 Sample Penetrator Payload

	Mass	Power
(a) passive seismometer 3 axis 4.5 h _z natural frequency 2180 bits per interesting event	.9 kg	129 milliwatt
(b) α-proton backscatter sensor 3 source-sensor units weight percent determination of C, O, F, Na, Mg, Al, Si, K, Ca, Ti, Fe 400,000 bits during first 8 days	.2 kg	100 milliwatt
(c) accelerometer single axis 100,000 bits during impact 31,000	.01 kg	170 milliwatt

Sample Penetrator Missions

To demonstrate the capabilities of a surface penetrator mission, the sample payload will be combined with sample implant strategies.

The sample payload, on each penetrator, is designed to measure natural seismic activity, measure in situ subsurface chemical compositions, and measure local surface layering. The orbiter will carry six penetrators and will deploy three of them in a seismic net and will deploy the other three to sample interesting terrain. Each penetrator can be implanted within a footprint 200 km long and 20 km wide. After the implant, the actual location will be determined to within 50 meters.

The operation sequence of each penetrator will begin with the measurement of the impact deceleration profile (50,000 bits of data). The data will be stored and read out to the orbiter during the first communication period.

During the next 8 days, the α -proton sensors will perform one measurement cycle each day. The data (50,000 bit each day), will be stored and transmitted to the orbiter.

The penetrator may then be commanded into a standby mode until the seismic net has been completed. Then, the seismometer will be activated to monitor natural seismic events and store its data. Each day the stored seismic data will be transmitted to the orbiter.

The active lifetime of each penetrator is limited by the capacity of the battery used to power the transmitter. Figure 1 shows how lifetime and daily data can be traded off.

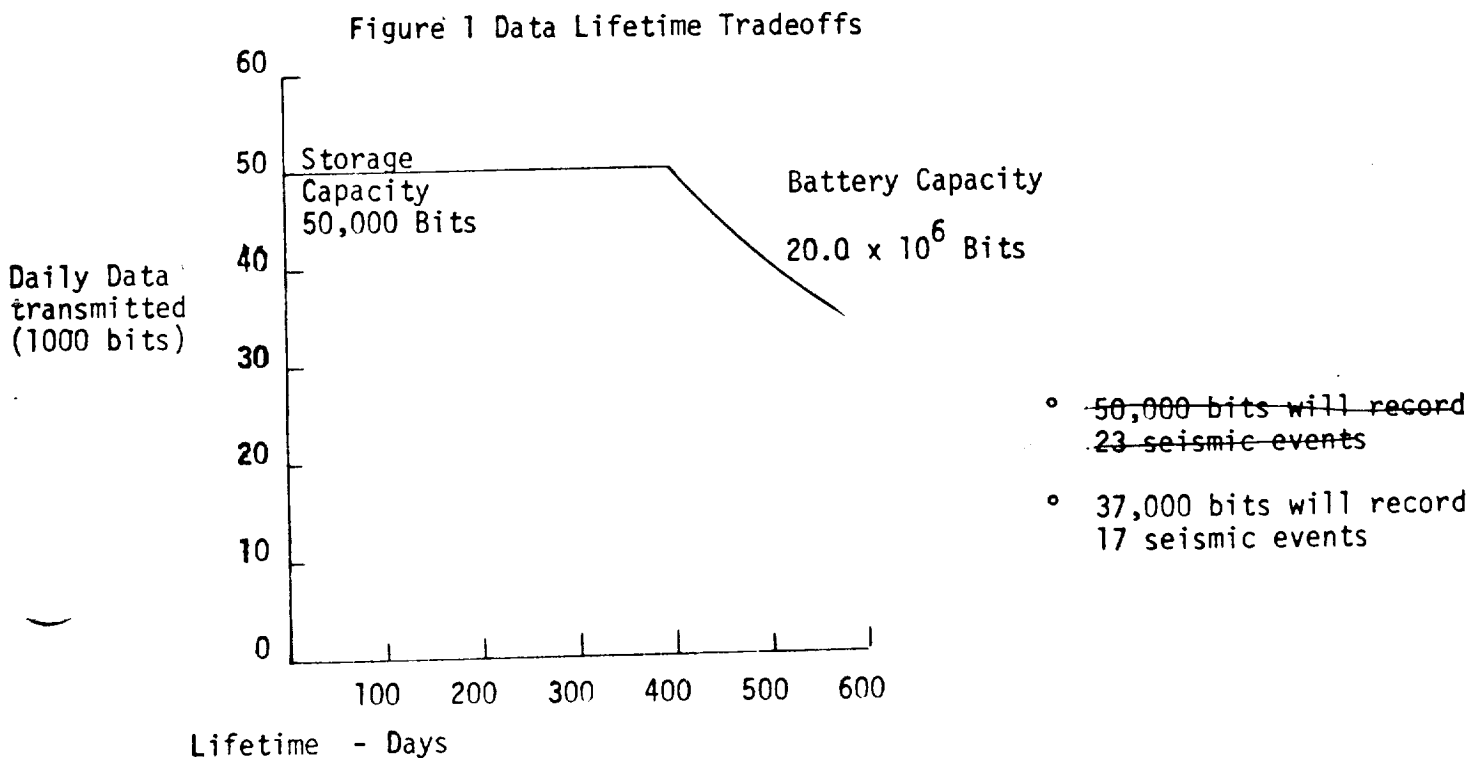


Table 2 A Sample Implant Strategy
South Polar Region

Penetrator No.	Time after arrival	Implant Lat	Implant Long
1	+20 days	-86°	240°
2	+30 days	-70°	240°
3	+50 days	-75°	15°
4	+70 days	-75°	70°
5	+100 days	-53°	240°
6	+160 days	-53°	298°

Seismic net formed by #1, #5, and #6 which are spaced 2000 km apart

- #1 targeted to laminated deposits unit
- #2 targeted to edge at South Polar Cap
- #3 targeted to etched plains unit
- #4 targeted to laminated deposits unit
- #5 targeted to cratered terrain unit
- #6 targeted to cratered terrain unit

Table 2 B Sample Implant Strategy
North Polar Region

Penetrator No.	Time after arrival	Implant Lat	Implant Long
1	+20 days	+59°	180°
2	+60 days	+70°	150°
3	+107 days	+65°	108°
4	+130 days	+80°	135°
5	+160 days	+90°	180°
6	+ 180 days	+83	0°

Seismic net formed by #1, #3 and #5, spacings are 1 - 3 2,000 km,
3 - 5 1,500 km, 1 - 5 2,000 km

- #1 targeted to plains unit
- #2 targeted to etched plains unit
- #3 targeted to etched plains unit
- #4 targeted to plains unit
- #5 targeted to permanent ice
- #6 targeted to residual North Polar Cap

Penetrator Configuration

Each penetrator will be separately carried to Mars within its own launch tube-bioshield. At the apoapsis before entry, the launch tube will be pointed by maneuvering the orbiter spacecraft and the penetrator deorbited by firing a small solid propellant motor. The penetrator will be slowed down to surface impact velocity (150 meter/sec) by a two-stage aerodynamic deceleration system. The penetrator will carry its science payload to rest after penetrating 1-15 meters into the surface of Mars.

Once on the surface, the science instruments will be powered from Radioisotope Thermoelectric Generators (RTG's) and will be sequenced through operating modes by an on board programmer. Data will be stored in an on-board memory (50,000 bits capacity) and transmitted to the orbiter during the few minutes each orbit when it is visible.

The implanted penetrator is shown in Figure 2.

Figure 2 Implanted Penetrator

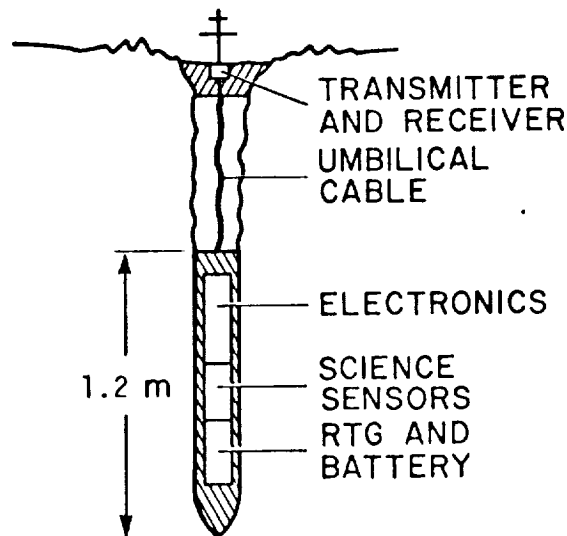


Table 3

Penetrator Weight Summary

Science	1.1 kg
Power	3.2 kg
Electronics	4.2 kg
Structure	22.5
Entry Body & Aero Decelerator	14.0
Deorbit Motor	7.2
<hr/>	
Total	52.2 kg

Table 4

Penetrator Science Instrument Environment

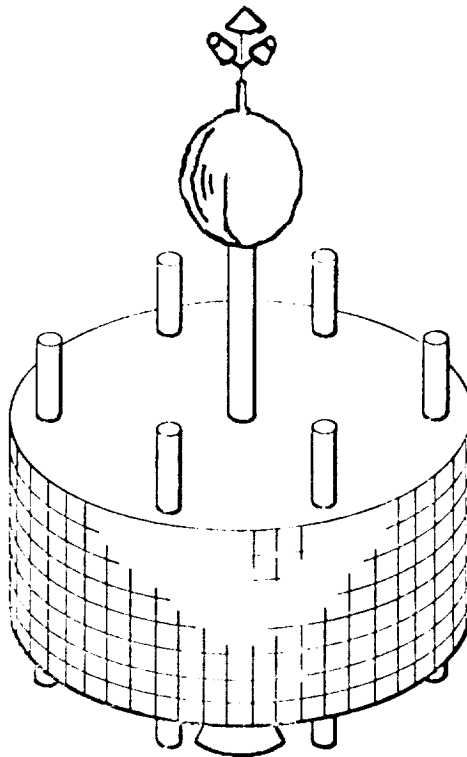
- ° 1800 g max deceleration
- ° 0.5 - 14.5 m depth below surface after implant
- ° 780 cc volume (7.6 cm dia x 17 cm long)
- ° 1.1 kg weight
- ° 200 milliwatt power

Orbiter Configuration

The orbiter spacecraft will be a modified version of the Pioneer Venus '78 Orbiter. It will spin for long term attitude control with the spin axis normal to the ecliptic. The Atlas/Centaur/TE 364 launch vehicle will be used (same as Pioneer Venus with added third stage).

Figure 3

Orbiter Spacecraft



Diameter= 2.55 m
Height = 3.99 m

Table 5
Orbiter Weight Summary

Pioneer Venus '78 Orbiter (w/o science instruments)	451 kg
+ contingency	+22
+ 6 launch tubes	+45
+ structure beefup	+37
+ relay communications	+5
+ attitude control fuel	+52
+ orbit insertion fuel	+144
+ 6 penetrators	+313
<hr/>	
Pioneer Mars '79 weight	1069 kg

Table 6
Orbiter Support to Penetrator Science

Commands for penetrator control:	75
Storage for penetrator data:	1×10^6 bits
Receive from 6 penetrators simultaneously	
Telemetry to Earth:	32 bits per sec (3 hrs. to send all stored penetrator data)

Planetary Quarantine

Since the Surface Penetrator Mission is not approved, formal planetary quarantine requirements have not been established yet. To assess PQ effects the Viking '75 PQ requirements have been examined.

The most severe impact of planetary quarantine is on the surface penetrators. The penetrators must be sterilized before they are launched from Earth and sterility must be maintained until they are separated from the orbiting spacecraft.

The sterility requirements will be satisfied by making the penetrator launch tube also a bioshield. Each penetrator, with its deorbit motor, will be sealed within its launch tube, and the entire assembly subjected to terminal sterilization. The launch tube assembly will then be attached to the spacecraft.

Each launch tube will be pressurized and the pressure will be monitored to assure that the bioshield has not broken. If a launch tube suffers a pressure loss, that launch tube will be replaced with a new sterile one.

The orbiter spacecraft will not be sterilized. The Mars PQ requirements will be satisfied by biasing the initial launch vehicle trajectory to miss the planet and by inserting the orbiter into an orbit which will not decay before the end of the quarantine period.

AERONOMY GEOLOGY MISSION

Introduction and Mission Concept

Mars upper atmosphere has been indirectly measured from several spacecraft, most recently from Mariner 9. Direct, in-situ measurements are, however, needed to provide a satisfactory description of the upper atmosphere.

Viking '75 and prospective Russian landers will begin to measure the atmosphere by making measurements along their trajectories as they descend to the surface. The complete picture of the atmosphere will however, require in-situ measurements over a large latitude and local time range.

The Aeronomy Geology mission will be designed to map the upper atmosphere and ionosphere by flying the orbiter with periapsis as deep in the atmosphere as possible. Measurements will be made during the low altitude part of the orbit near periapsis and coverage in local time will be achieved by controlling the orbit period so that periapsis passages drift around the planet.

To satisfy Planetary Quarantine requirements, the outside of the spacecraft will be decontaminated to remove organisms which might sluff off into the atmosphere. Complete sterilization will be avoided by raising periapsis out of the atmosphere after the end of the mission.

The orbiter spacecraft's low periapsis altitude and complete longitude coverage provide an ideal opportunity for remote sensing of the surface, so a geochemistry instrument is included in the payload.

The orbiter's elliptical orbit and local time coverage provide an ideal opportunity to map the solar wind interaction region, so suitable instruments are included in the payload.

This mission offers a low cost option for Mars exploration because it requires minimum changes from Pioneer Venus '78 in both the spacecraft design and the instrument payload.

Science

The key Aeronomy objective for this mission is measurement of the neutral and positive ion composition and heat balance of the ionosphere.

Measurements are crucial for constructing models of the current state of the atmosphere and inferring its evolution. (See the report "Exploration of Mars after 1976" for a more complete discussion.)

The key Geology objective for the mission is measurement from orbit of surface elemental abundances, both global averages and local variations from average. The instrument chosen is a γ ray spectrometer because of its compatability with the spacecraft design. The instrument can be based on the Apollo instrument or an instrument which may be developed for the Lunar Polar Orbiter.

The third key objective for the mission is to map the entire region of the solar wind interaction with Mars, including the tail.

The sample payload used to satisfy these objectives is selected from instruments chosen to fly on the Pioneer Venus '78 orbiter, plus the γ -ray spectrometer. It is summarized in table 7.

Mission Description

The orbiter spacecraft will initially be inserted into a 24 hour orbit with about 500 km periapsis altitude. After a few days to verify the orbit, periapsis will be lowered to 115 km (limited by spacecraft heating from aerodynamic drag). During the mission, periapsis will be actively controlled to remain within a range of a few kilometers.

The orbiter will be inserted into an orbit with inclination of 118° (to Mars equator), to minimize periapsis motion during the mission. Periapsis may be located at $+30^\circ$ lat, and the orbiter will be within 1000 km of the surface between latitudes -10° and $+60^\circ$. Or, periapsis may be located at -55° lat, and the orbiter will be within 1000 km of the surface between latitudes -20° and -62° . The period will be about 24 hours.

During the periapsis period of each orbit when the spacecraft is within 1000 km of the surface (about 30 min.), the atmosphere and ionosphere instruments and the γ ray spectrometer will collect data and store them in the spacecraft memory. During the rest of the 24 hour orbit, the telemetry system will read out stored data to Earth. The particle and field instruments will collect data during the entire orbit for storage and transmission to Earth.

The spacecraft orbit will not be synchronous with Mars rotation, so periape will move around the planet. Peripse, and hence the location of atmosphere and surface data collection, will move

Table 7 Aeronomy Geology Payload

Atmosphere Composition Instruments

(a) Neutral Mass Spectrometer 1 - 46 AMU 530 bit/sec max output	4.9#	7.9 watt
(b) Ion Mass Spectrometer 20 species in range 1 - 60 AMU 70 - 350 bit/sec output	2.5#	0.8 watt
(c) Retarding Potential Analyzer 40 bit/sec output	4.2#	2.8 watt
(d) Electron Temperature Probe 130 bit/sec output	2.9#	3.0 watt

Surface Chemistry Instrument

(e) γ -ray spectrometer cooled Ge detector boom mounted 1000 bit/sec output	17.0#	12.0 watt
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Solar Wind Interaction Instruments

(f) Solar Wind Plasma Analyzer 50 - 8000 eV ion flux 1 - 500 eV electron flux 9 bit/sec output	6.6#	3.0 watt
(g) Magnetometer .1 γ to 100 γ range 0 to 10 h _z bandwidth boom mounted 27 bit/sec output	4.0#	1.5 watt

TOTAL	42.1#	30.0 watt
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19.1 kg

completely around Mars through all local times.

At the end of the mission, nominally after 680 days in orbit, periapsis will be raised up out of the atmosphere to about 1000 km altitude. The spacecraft will then operate only particle and field instruments till the end of its life.

Orbiter Configuration

The orbiter spacecraft will be heavily based on the Pioneer Venus '78 Orbiter. The only changes will be to the thermal control and power subsystems to allow operation at Mars, and the addition of a boom for the γ ray spectrometer. The spacecraft will spin for long term attitude control with its spin axis normal to the ecliptic. The Atlas Centaur launch vehicle will be used (same as Pioneer Venus).

Figure 4
ORBITER SPACECRAFT

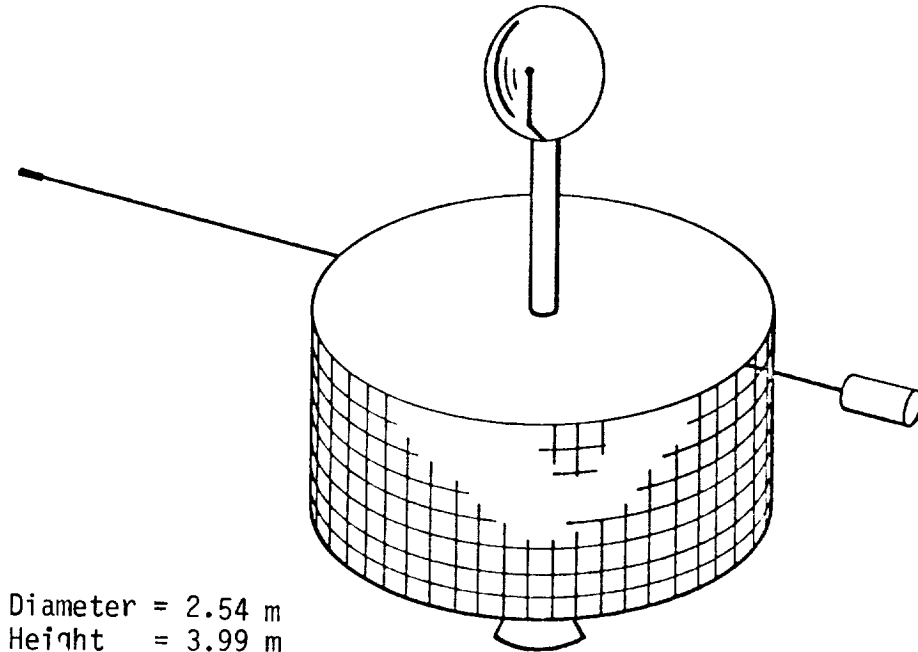


TABLE 8

Weight Summary

Pioneer Venus '78 Orbiter (w/o science instruments)	451 kg
+ contingency	+45
+ power and thermal control	+10
+ attitude control fuel	+12
+ science instruments	+19
<hr/>	
Pioneer Mars '79 weight	537

TABLE 9

Orbiter Support To Science

Instrument weight: 19 kg
Instrument power: 50 watt
commands 75
Data storage 1×10^6 bits
Telemetry to Earth 32 bits/sec (6 hour to send all stored data in memory)

Planetary Quarantine

Since the Aeronomy Geology Mission is not approved, formal planetary quarantine requirements have not been established. To assess PQ effects, the Viking '75 PQ requirements have been examined. They effectively require any object that impacts Mars' surface to be sterilized.

The mission requires the orbit periapsis to be far enough into the atmosphere that the orbit, if unchanged, would decay before the end of the quarantine period (Dec. 31, 2018). To prevent orbit decay, and subsequent spacecraft impact on Mars, the spacecraft will raise its orbit at the end of the nominal mission to ensure a sufficiently long lifetime. The spacecraft will incorporate sufficient redundancy to perform the orbit raising maneuver with an acceptable probability of success.

Since the spacecraft will pass through the atmosphere, the outer surfaces will be decontaminated before launch. The launch vehicle will be biased to miss Mars.

Pioneer Mars Reference Documents

1. Pioneer Mars 1979 Mission Options report - SAI 120 - M1
January 29, 1974

Preliminary study by SAI which concluded that Aeronomy/Geology Orbiter and Orbiter with Surface Penetrators are low cost missions which can perform useful scientific investigations at Mars.

2. Pioneer Mars Surface Penetrator Mission
Mission Analysis and Orbiter Design - August 1974

Report of Phase A study by Hughes Aircraft Company. Mission analysis studies are included and orbiter spacecraft modifications from Pioneer Venus '78 are described.

3. Mars Penetrators: Subsurface Science Mission - August 1974

Report of Phase A study by Sandia Laboratories. Science instruments and penetrator design are described.

4. Pioneer Mars Aeronomy-Geology Mission - August 1974

Report of Phase A study by Hughes Aircraft Company. Mission analysis studies and orbiter spacecraft modifications from Pioneer Venus '78 are described.